AIRS Radiance Validation Report of March 2003

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We have begun our validation of level 1b radiances for the near-real-time data assimilation subset of 281 channels using DAO forecasts, analyses, collocated radiosondes from the operational stream, and NCEP analyses. The objective is to assess the quality of the AIRS/AMSU A level 1b radiances and the various forward models used. We used both the AIRS team stand-alone radiative transfer for AIRS algorithm (SARTA) provided by Larrabee Strow and a preliminary version of the community OPTRAN code developed at NOAA NESDIS to compute brightness temperatures from temperature, humidity, and ozone fields from the various backgrounds. Overall, we found that the SARTA code performed very well both in terms of accuracy and efficiency. We developed a fast approximate Jacobian of the code so that it could be used within our existing one-dimensional variational (1DVAR) cloud clearing and retrieval scheme.

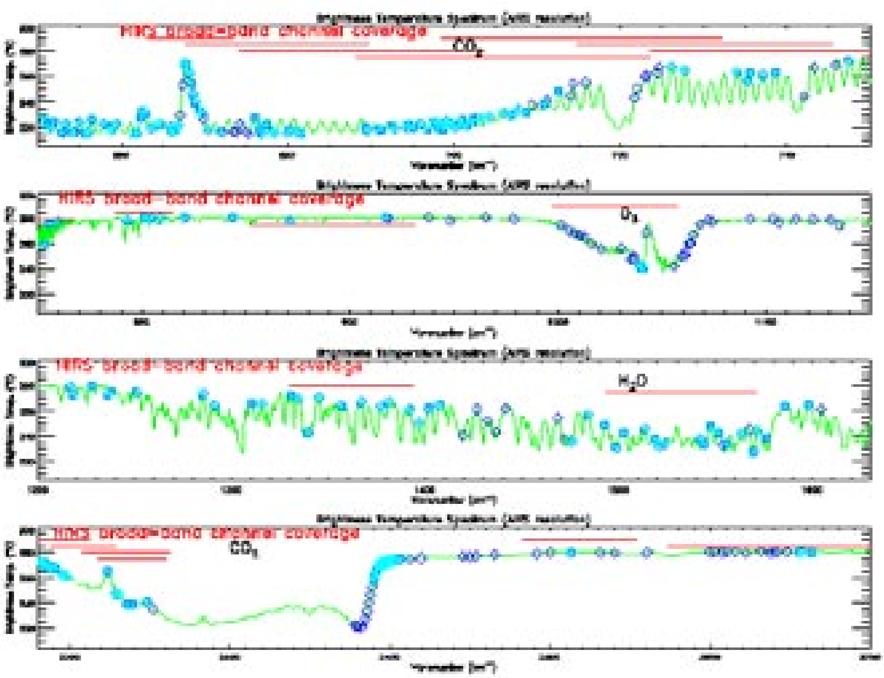
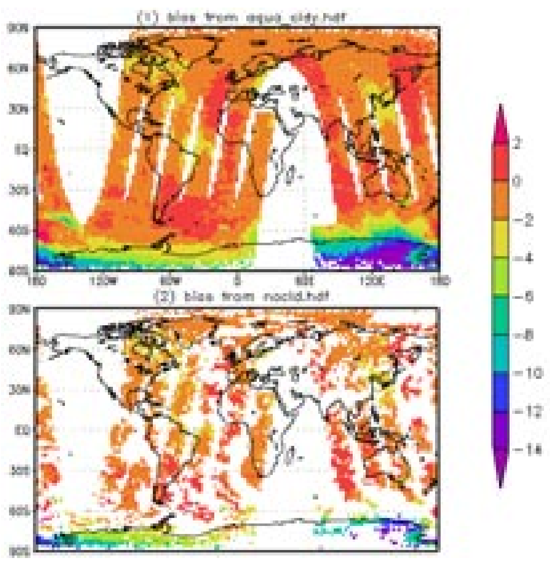


Figure 1: Simulated brightness temperatures at AIRS spectral resolution showing 281 near-real-time 281 channels (dark blue diamonds) and preliminary 1DVAR channel set (light blue stars)

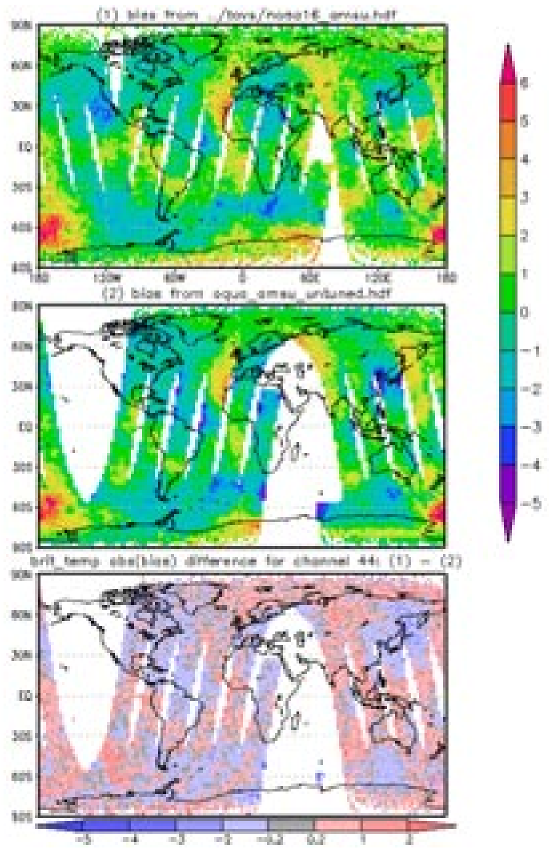
Figure 1 shows the important absorption bands in the AIRS spectral range and the channels available in the near-real-time data set. For reference, single HIRS channel spectral bands are shown above. We will now show examples of some of the more interesting channels identified in our radiance validation.

Figure 2 shows one of the highest peaking channels in the 15μm band (668.64 cm^{-1}). Several interesting features can be seen. Some of the orbits exhibit positive observed minus forecast (O-F) values (red), while other negative (orange). We believe that this is an artifact of treating the satellite data as if it were taken at a single synoptic time. The DAO model produces realistic stratospheric tides. However, the forecast and analysis fields are produced only once per 6 hours. All data is treated as if it were taken at this time. For fields with significant temporal variability on hourly time scales (such as temperature in the upper stratosphere), this can create an orbital signature in O-F. We have noted such a signature previously from the NOAA Stratospheric Sounding Unit (SSU).



Large negative values of O-F are present over Antarctica indicating that the forecast temperature field is too warm in the range of altitudes that affects this channel. To gain more insight into this bias, we examine O-F brightness temperatures from the highest peaking AMSU channel in figure 3. We do not see these large values of O-F over Antarctica for AMSU channel 14 that also peaks in the upper stratosphere. The high-peaking AIRS channel has more of a tail in the weighting function that produces some sensitivity to mesospheric temperatures. Therefore, we believe that the O-F bias in the AIRS channel is caused by a bias in the DAO's mesospheric temperature field. In fact, S.-J. Lin (private communication) confirmed that a recent change to the gravity wave drag scheme in the DAO model led to improvements in stratospheric winds but produced a mesospheric temperature bias that would explain the large O-Fs seen above.

Some similar features in O-F brightness temperature can be seen in both the high-peaking AMSU and AIRS channels. The tidal signature is evident in the AMSU channel although much reduced as compared with the AIRS channel. Both the NOAA 16 and Aqua AMSU produce similar values of O-F, but there appears to be more of an asymmetrical cross-track bias in the Aqua AMSU.



The cross-track bias is even more striking in Aqua AMSU channel 6 as shown in figure 4 where the side to center bias is several degrees. This type of bias appears in all of the NOAA AMSU instruments that we have used for monitoring and assimilation. However, the maximum side-to-side bias in the NOAA AMSU instruments is only about 1K. A cross-track bias correction is necessary if the data are to be effectively assimilated. The cause of the bias is thought to be an artifact produced by contamination of the satellite and reflected cold-space and Earth radiance in the instrument (especially the side lobes) that is not removed in the calibration process. A partial correction for some of the NOAA AMSU instruments has been provided. The problem appears to be more serious in the Aqua AMSU and has since been studied by B. Lambridgsen at JPL. It appears that providing a correction will be non-trivial. The current DAO bias correction scheme was not able to completely remove the bias.

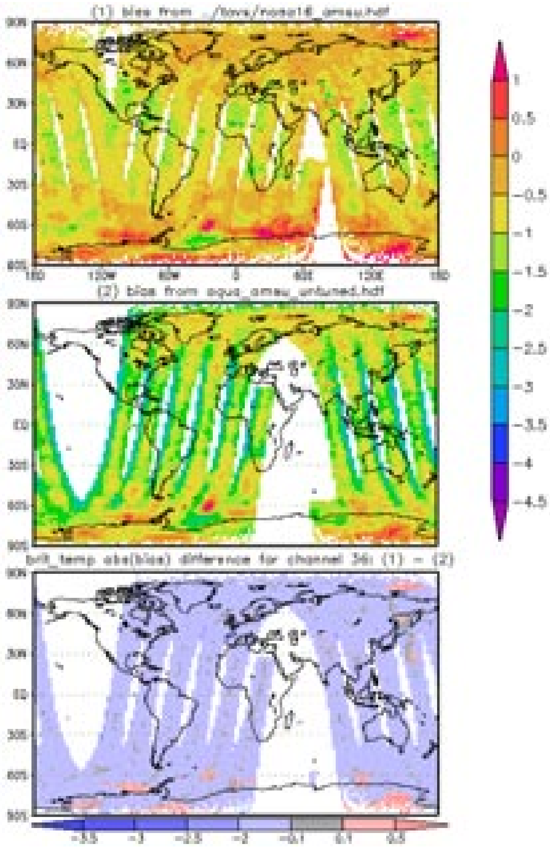


Figure 5 shows O-F brightness temperatures for a lower-tropospheric/window channel in the 9-10μm band. Channels in this band have a high sensitivity to desert dust aerosol. When the clouds are removed in the bottom panel, large negative values of O-F are apparent over Africa. This could be due to several factors including aerosol (not taken into account in the forward radiance calculation), residual cloud contamination, and errors in the surface emissivity and/or skin temperature. These large values of O-F over Africa are not as apparent for channels in the 11μm and 4μm windows and for this reason these pixels pass the cloud detection checks. This points to either aerosol or emissivity errors as the explanation. We are using the surface emissivity data set of Wilber *et al.* (1999) that is also used by the CERES team that we believe is fairly accurate for the frequency shown here.

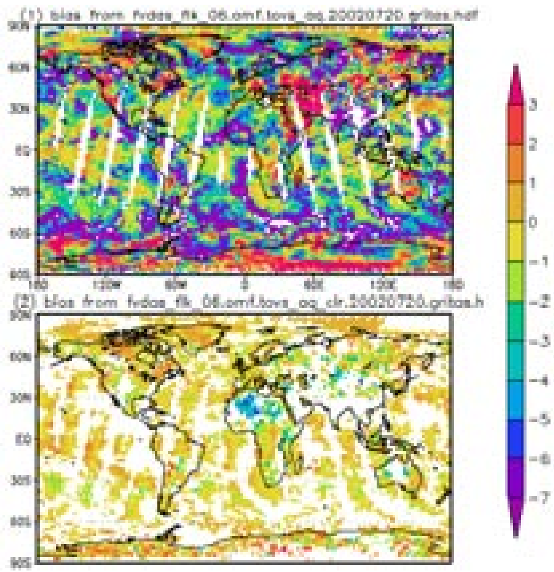
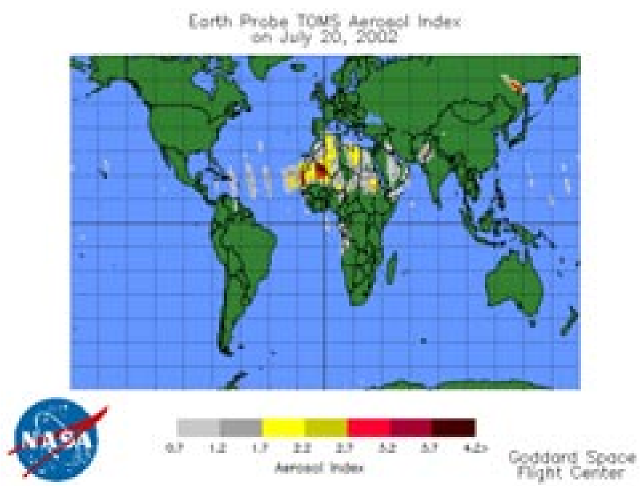
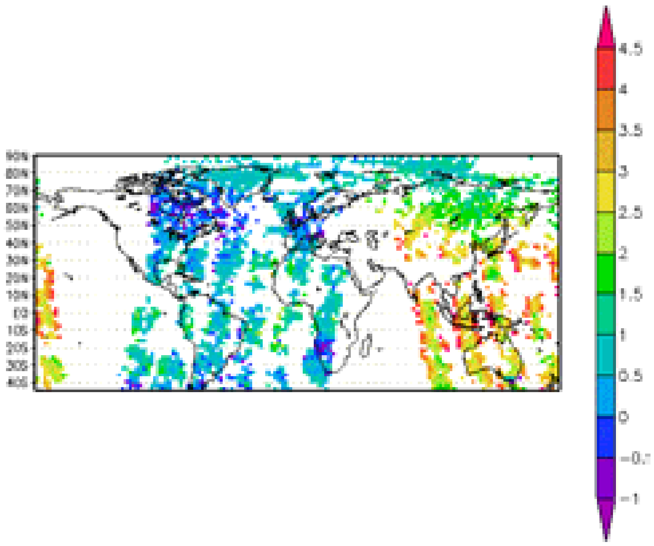
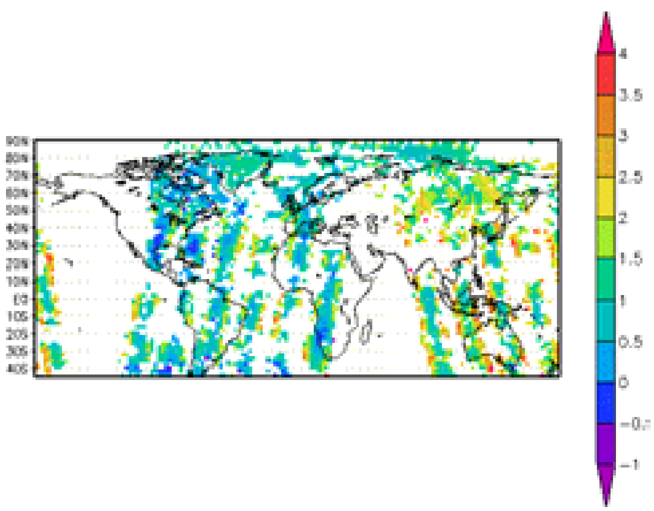


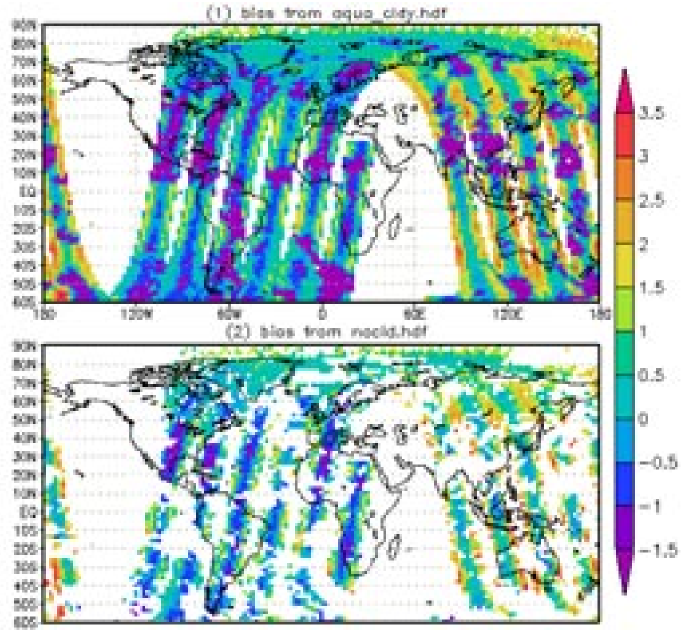
Figure 6 shows a map of the TOMS aerosol index for this day that indeed shows a dust outbreak over northern Africa. We therefore believe that at least some of the signal is due to airborne dust. Weaver *et al.* (2003) have investigated the aerosol effect on TOVS channels and have shown that significant effects of desert dust on TOVS is present. Therefore, AIRS channels should also be affected.



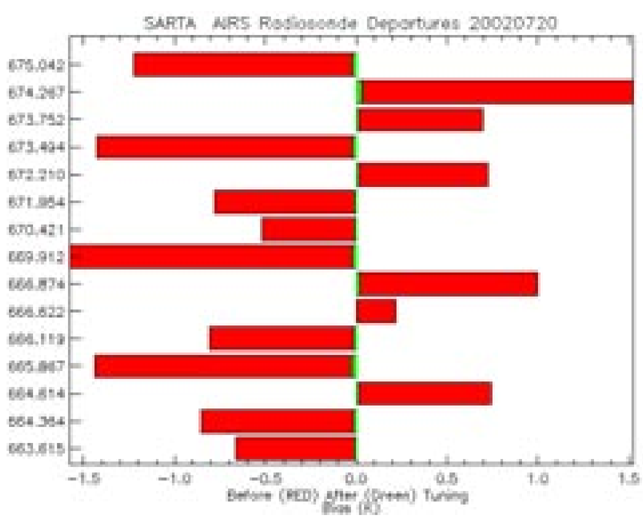
The next set of figures illustrates how using the O-F metric can clearly identify channels that are affect by non-local-thermodynamic-equilibrium (non-LTE) effects. These effects were expected for high-peaking channels in the 4.3µm band. However, it was not known exactly how many channels would be affected. Figure 7 shows O-F brightness temperatures for the AIRS channel at 2382.7 cm^{-1}. This channel is sensitive to high clouds so cloud detection has been applied. A clear positive bias in the daytime orbits (right side of the figure) indicative of non-LTE is seen. The non-LTE effects decrease further from the band center as indicated in figure 8 for a channel at 2384.7 cm^{-1}. However, non-LTE is still present in this channel as indicated by the higher biases at larger satellite and solar zenith angles. Non-LTE effects are also observed at the long-wavelength end of the 4.3μm band as shown in figure 9.

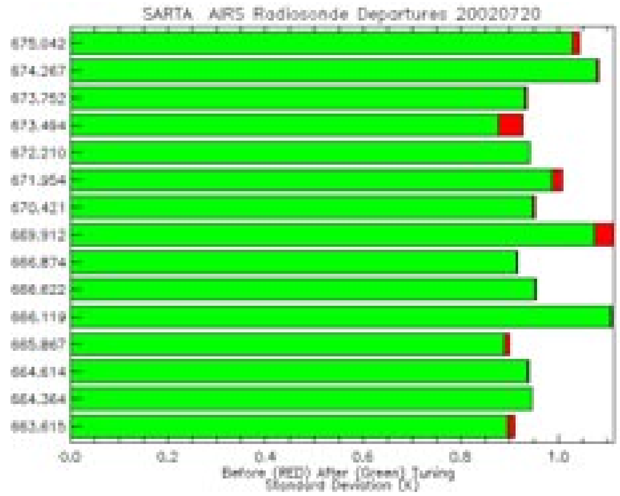




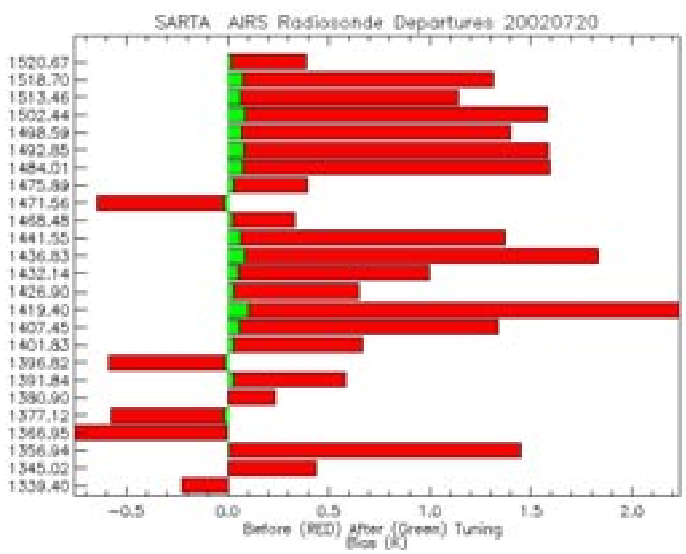


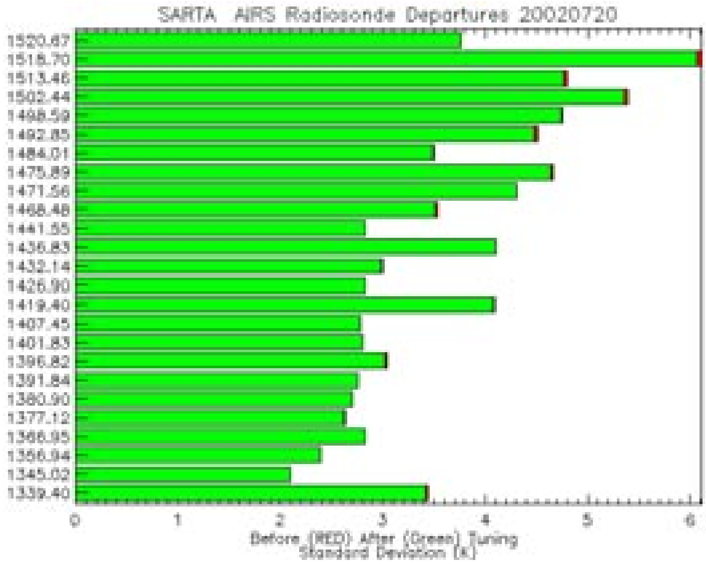
Finally, we show some comparisons of AIRS brightness temperatures with those computed from collocated radiosondes. Temperatures and humidities above those reported by the sondes are filled in with DAO analyses. Figure 10 shows the bias with respect to radiosondes using a preliminary version of SARTA that was not optimized for the focus day. Even so, the biases are relatively small, generally between +/- 1K. The standard deviations, shown in figure 11, are also small, generally less than 1K. We have evaluated more recent AIRS data with a more consistent version of SARTA and the results were somewhat improved. The OPTRAN code did not perform as well as SARTA and results will not be shown here. OPTRAN is currently being optimized by personnel at NOAA.





Figures 12 and 13 show biases and standard deviations for channels in the 6.7μm water vapor band. Biases and standard deviations are typically higher for water vapor channels as there are increased representativeness and temporal/spatial errors/differences for comparisons between satellite data and point measurements. Even though we have filtered out certain types of radiosondes with known biases, radiosondes and the DAO background still typically have biases especially in the upper troposphere. The biases shown here are somewhat smaller than those we see with the 6.7μm TOVS channels, indicating that the spectroscopy and parameterizations in SARTA are quite good. The standard deviations are similar to those of the TOVS channels.





Our overall assessment of AIRS data is that both the radiometric calibration and the accuracy of the radiative transfer code (SARTA) are excellent. Biases are typically smaller than those of comparable TOVS channels. In addition, the SARTA code is computationally efficient and this is an important attribute for the assimilation of AIRS data. Through the radiance validation, we have identified a few noisy channels (not shown) as well as those affected by aerosol and non-LTE. Our radiance monitoring showed that there is information about the mesospheric temperature that is not present in AMSU data. We repeated our analysis using NCEP analyses and the results were very similar.

We are currently performing the first assimilation experiments with AIRS data. Preliminary results have been presented at AIRS science team meetings and the EOS IWG meeting. Based on the radiance monitoring, we performed experiments where the top analysis level was raised from 0.4hPa to 0.02hPa. We have seen large changes in the mesospheric temperatures and winds as well as in upper tropospheric humidity by assimilating AIRS data. We are currently evaluating the impact by using independent data. We also plan to evaluate medium-range forecasts. Finally, we plan further comparisons of our 1DVAR analyses with collocated radiosondes.

References

Weaver, C. J., Joiner, J., and Ginoux, P., Mineral aerosol contamination of TOVS temperature and moisture retrievals. *J. Geophys. Res.,in press,* 2003.

Wilber, A. C., Kratz, D. P., and S. K. Gupta, Surface emissivity maps for use in satellite retrievals of longwave radiation, *NASA Tech. Pub. 1999-209362,* 30pp., Hanover, MD.